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STAGING OPTIONS FOR THE
AIR FORCE'S ELECTRONIC COMBAT
TEST CAPABILITY: A COST ANALYSIS

THESIS

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AFIT/GCA/LSY/90S-3

The opinions and conclusions in this paper are those of the author and are not intended to represent the official position of the DOD, USAF, or any other government agency.

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STAGING OPTIONS FOR THE AIR FORCE'S ELECTRONIC COMBAT TEST CAPABILITY: A COST ANALYSIS

THESIS

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of the Air Force Institute of Technology
Air University
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Requirements for the Degree of
Master of Science in Cost Analysis

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Preface

The purpose of this study was to find the lowest cost aircraft staging base for the Air Force's proposed Electronic Combat Test Capability. The Electronic Combat Test Capability is the Air Force's attempt to achieve greater realism in operational testing of new and modified weapons systems.

To find the lowest cost aircraft staging base, a life cycle cost analysis was performed on six alternative options. The cost analysis was conducted using generally accepted methods of evaluating capital investment projects and in accordance with Air Force Regulation 173-15, Economic Analysis and Program Evaluation for Resource Management.

Most of the data used in this analysis was provided by the Air Force Operational Test and Evaluation Center, Kirtland AFB, New Mexico. I am heavily indebted to the Center's personnel and especially to Lt Col Robert Greenlee who is the Center's Deputy Director for Resource Management.

I would like to thank my thesis advisor, Lt Col John Dumond for his advice, patience and assistance. I would also like to thank my thesis reader, Dr. Roland Kankey.

Finally, I would like to extend a heartfelt thanks to my wife Katie and my two children for their unceasing support.

Joseph J. Landino, Jr.

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Abstract

This study's purpose was to identify the lowest cost aircraft staging base(s) for the Air Force's proposed Electronic Combat Test Capability (ECTC). The ECTC will be an electronic simulation of a Soviet integrated air defense sector. If constructed, the ECTC would be located at the Utah Test and Training Range. A literature review revealed that there has been a need for a test capability like the ECTC since the Vietnam War era.

To find the lowest cost aircraft staging base(s), a 25 year life cycle cost analysis (CA) was performed for the sponsoring agency, the Air Force Operational Test and Evaluation Center (AFOTEC). The CA evaluated six staging alternatives that were identified by AFOTEC. Two significant portions of the CA were to estimate the investment costs for each alternative and to cost the aircraft mission workload projected for the 25 year life cycle. The aircraft mission workload comprised the various test and support aircraft that would be involved in ECTC operations.

The CA revealed that the lowest cost staging option was to stage aircraft operations from their home bases where the test and support aircraft are stationed instead of constructing a new or modifying an existing base.

Staging Options for the Air Force's Electronic Combat Test Capability: A Cost Analysis

I. Introduction

General Issue

Electronic combat technologies are used by the United States Air Force (USAF) in combat. Electronic combat is a specialized task that affects every Air Force mission (3:64). It is aimed at reducing the odds that a plane will get shot down (18:12). The following passage defines electronic combat and its components:

> Electronic Combat involves actions to neutralize or destroy an enemy's electromagnetic capability and to protect friendly electromagnetic capabilities. It includes electronic warfare as well as elements of command, control and communications countermeasures and suppression of enemy air defenses. Electronic warfare involves the use of electromagnetic energy to determine, exploit, reduce or prevent hostile use of the electromagnetic spectrum. Suppression of enemy air defense operations have the purpose of neutralizing, destroying or temporarily degrading an enemy air defense system in a specific area by physical and or electronic measures. Command, control and communications countermeasures involves offensive and defensive actions that are designed to deny information to an enemy, protect friendly command, control and communications and to destroy or degrade enemy command, control and communications capabilities. (3:64)

The USAF lacks an integrated, open-air capability to operationally test new electronic combat systems.

Background

The push for a capability to test the electronic combat systems of the United States Air Force had its start during the Vietnam War.

> Experience in Southeast Asia in the 1960s and early 1970s demonstrated the need for more realistic operational test and evaluation. Much of the equipment employed there had not been adequately tested and, [initially], did not work as expected. The U.S. lost many aircraft in that conflict. The costs of inadequate operational testing [electronic combat testing], both in personnel and in equipment, are high. (9:2)

In 1988, General William Kirk, Commander of United States Air Forces in Europe, expressed the need for better ways to train and test Air Force flight crews in electronic combat doctrine, tactics and employment:

> United States Air Forces in Europe electronic combat training has improved significantly in the past few years. This has improved our weapon systems and increased our survivability. However, we realize we must continue to search out new and better means to train our personnel at all levels, from the air crew commander to the battle commander. (15:63)

As stated previously, the Air Force needs an integrated, open-air electronic combat test capability so that important operational information from testing and training can be obtained before battle. This open-air electronic combat test capability should not be confused with any of the electronic combat test laboratories and chambers within the Department of Defense. An example of one of these is the anechoic test chamber at Eglin Air Force

Base, Florida. In a chamber such as this, the testing is done while the aircraft is on the ground.

Specific Problem and Justification for Research

There is a consensus that the USAF needs an electronic combat test capability. The USAF acknowledged this lack of capability by validating Statement of Need 01-85, Electronic Combat Test Capability (ECTC) at the Utah Test and Training Range (UTTR), on 1 May 87 (2:1). Statement of Need 01-85 was prepared in accordance with Air Force Regulation 57-1, Operational Needs. This regulation governs how Statements of Need are prepared and submitted to meet new Air Force mission requirements (4:1).

This Statement of Need calls for the development of an electronically simulated Soviet integrated air defense sector (IADS). New electronic combat systems would fly over the IADS and be exposed to its electronic emissions. This would enable the USAF to find out if the new systems work as needed. Currently, many of the electronic combat systems that are employed have not been adequately tested from an operational standpoint. Therefore, data on how these systems function in an operational environment is obtained only in real combat operations. This is obviously dangerous because some of these systems may not function as intended.

The technology to accomplish the development and construction of the ECTC is not a limiting factor. Most of

the electronic threat simulation systems that would comprise the ECTC infrastructure exist today.

The major limiting factor is the funding for the ECTC. Fielding a full version of the ECTC is estimated to cost $1.81 billion over six years (1). This estimated cost is very expensive given the current atmosphere of reduced funding for the Department of Defense and the Air Force.

For the ECTC to survive in the defense budget, a low cost way of fielding and operating it must be found. The focus of this research is to find the lowest cost aircraft staging base(s) for the test and support aircraft that will fly over the ECTC. This question needs to be answered: What existing or new aircraft staging base(s) would result in the lowest the life cycle cost for the ECTC?

Research Objective

The basic objective of this research is to identify the lowest cost aircraft staging option. To do this, a cost analysis (CA) was performed. Chapter V contains the results of the CA. The CA looks at the life cycle cost of staging aircraft operations from six alternative groups of locations.

Research Questions

The first four questions must be answered to perform the CA. The fifth question satisfies the objective of this

research. The sixth question addresses the robustness of the solution.

1) What is the total mission time for each ECTC staging location?

2) What are the operating and maintenance costs for this project (exclusive of operating the ECTC electronic simulation equipment).

3) How many missions and aircraft are projected to use the ECTC?

4) What existing capital investment evaluation model should be used to evaluate the alternative staging options?

5) Based on the above inputs, what is the lowest cost aircraft staging option?

6) Is the lowest cost staging option sensitive to changes in the following CA inputs:

a) The mission workload.

b) The discount rate.

II. Literature Review

Topic Statement and Explanation of Terms

This literature review provides a background on the current thinking on and the issues that affect electronic combat testing in the United States Air Force. It also contains a more thorough description of the ECTC and its composition. It concludes with a discussion of capital investment evaluation methods commonly used to evaluate capital investment projects.

Scope and Limitations

The following discussion of the literature provides a brief historical perspective of electronic combat, addresses electronic combat doctrine and tactics as well as current electronic combat thinking and employment strategies, describes the new weapons systems that are in development to meet the emerging threat, describes the inadequacies in the Air Force's ability to test these new weapons systems, and describes the proposed ECTC. The section on capital investment evaluation methods discusses different ways to evaluate capital projects.

Professional journals, textbooks, and Air Force official publications, information, and regulations were used for the data in this review. The data used is

unclassified and no attempt is made to address the technical aspects of electronic combat.

Method of Treatment and Organization

The discussion of the literature is organized by topic. The topics are presented in a logical sequence to help the reader better understand electronic combat and capital investment evaluation methods.

All the sources used in the electronic combat portion of this review were published since 1986. Four of the sources are official Air Force documents. The sources used for the capital investment evaluation methods section are cost accounting texts and AFR 173-15.

Historical Perspective

Using the electromagnetic spectrum for combat purposes has its roots in the beginning of the 20th century. An example of this was the "the radio communications countermeasures used during the Russo-Japanese War of 1904" (10:1).

Electronic combat as a weapon was further advanced in World War II "when the British and Germans successfully intercepted each other's radar" (18:16).

The Vietnam War was a turning point for electronic combat; after initial problems (because of inadequate testing), it was used with some success by both sides during

this conflict (15:13). In Vietnam, it was used by U.S. fixed wing aircraft and helicopters. The North Vietnamese used "tube launched, infra-red seeking, surface-to-air missiles . . . [starting] in 1971" (17:44) to shoot down helicopters.

In the decade of the 1980s, the United States and its allies continue to use electronic combat. In April of 1986, the United States' air attack on Libya, Operation Eldorado Canyon, used anti-radiation missiles as part of the electronic combat employment package (11:61). The Israelis continue to use a full range of electronic combat technologies in their air operations over Lebanon (10:1).

The continuing history of employment is what adds to the doctrine and tactics of electronic combat. The following is a discussion of electronic combat doctrine and tactics.

Doctrine and Tactics

The doctrine and tactics of electronic combat are its foundation. This foundation has been evolving "since the Wright brother's first flight at Kitty Hawk" (3:63).

The doctrine and tactics for employment of electronic combat resources in the Air Force can be found in Air Force Manual 1-1, Basic Aerospace Doctrine (7). The doctrine and tactics developed are aimed at defeating the Soviet Integrated Air Defense System.

Electronic combat in the United States is founded on threat, doctrine and technology. The threat establishes the need for electronic combat. Basic Air Force doctrine shapes the concept while technology provides the means. The primary influence on electronic combat is the Soviet Integrated Air Defense System (IADS). The Soviet IADS has three primary missions. First it provides detection, warning and control. The second mission is to destroy an opponent's aircraft. The third mission is to degrade attacking aircraft capability through the use of communications and navigation system jamming. (3:63)

Electronic combat history, doctrine, and tactics merge to form current thinking and employment strategies.

Current Thinking and Employment Strategies

The Air Force has established a biennial symposium to trade ideas on electronic combat (14:53). The commander of the Air Force's Tactical Air Warfare Center chairs the symposium (14:53). Authors present topic papers to discussion panels that are chaired by a general officer (14:53).

In 1987, these new ideas were presented:

1) The concept of having a "playbook" for preplanning [electronic combat] support to tactical operations.

2) The use of unmanned pure harassment drones in suppression of enemy air defense operations.

3) A proposal to use joint assets to destroy frontline [missile] radar sites.

4) The use of dedicated protection measures to ensure the realization of significant enhancements to attack force survivability.

5) The ability to train effectively to meet the electronic threat.

> 6) A proposal to reduce the confusion among the "uninitiated" regarding when and how [electronic combat] contributes to the overall mission.
>
> 7) [The] problems facing [the Air Force] with the postulated fielding of new generation passive-guided, air-to-air and surface-to-air missiles designed to target [the Air Force's] fighters. (14:54-56)

Air Force policy makers believe that it is important to thoroughly analyze and plan before employing electronic combat systems. "Electronic combat planning and integration activities [should] begin in peacetime with a continuous examination of potential adversaries' equipage, force composition and capability" (3:70). During the analysis and planning stage, the Air Force examines the many different types of enemy electronic threats that may be faced in an engagement.

This need for analysis and planning led the Department of Defense to set up the Joint Electronic Warfare Center in 1980 (11:61). The Center evaluates potential battle situations. Specifically, they evaluate the potential threat that will be faced and recommend the weapons system(s) that should be used (11:61-62). The Eldorado Canyon mission mentioned previously was planned by the Center (11:61).

After the planning and analysis is done, coordinating the proper use of the Air Force's electronic combat assets is another task.

> Today's battlefield commander requires the assistance of an extensive staff due to the complex problems he faces. With [the] recognized need of employing electronic combat assets as a unified mission area, there is an obvious need to advise the commander as to the best use of these forces. (10:4)

In reaction to this need for help, the Air Force has established the position of Electronic Combat Coordination Officer (10:4). This officer sits on the wing battle staff to advise the commander on how best to use the wing's electronic combat assets (10:4).

When Air Force analysts and planners evaluate the future electronic threat situation, their thinking often leads to what new weapons systems are needed to maintain technological superiority over the enemy. The following section discusses four new electronic combat systems.

New Weapons Systems

There are four new systems that the Department of Defense is planning to field in the early 1990s that will have a major impact on the Air Force's ability to function on the electronic battlefield. They are the Advanced Self Protection Jammer, the Mark XV Identification Friend or Foe, the Joint Tactical Information Distribution System, and the Integrated Electronic Warfare System.

The Advanced Self Protection Jammer is an "internally mounted electronic countermeasures system intended for most Navy and Air Force frontline fighters" (12:78). It has two

advantages that make it more effective than current electronic countermeasures systems: 1) because it is installed inside aircraft, it does not adversely affect aerodynamic performance (12:78); and, 2) it will provide "aircraft with better self-protection capabilities against modern enemy radar-guided, air- and ground-launched weapons" (12:78).

The Mark XV's function is to tell its operator whether an aircraft is an enemy or a friend. This prevents friendly aircraft from being shot down. Until the Mark XV's deployment, "the lack of a standard identification friend or foe system among North Atlantic Treaty Organization countries, which operate about 40 different models of tactical aircraft, [will] make identification of friendly aircraft difficult" (12:80).

The Joint Tactical Information Distribution System's development was spurred by a need for all the services to be able to communicate in a common way.

> Joint Tactical Information Distribution System (JTIDS) is a secure, jam-resistant, high-capacity, digital data and voice communications system to be used by the Air Force, Army, Navy and Marine Corps as well as NATO allies for aircraft, ships, and ground command and control and air defense centers . . . . [It] uses so-called Time Division Multiple Access technology, a communications method that enables hundreds of users to share a radio network, much like a telephone party line, and to use it simultaneously without interference. (12:80-1)

The real advantage of the Joint Tactical Information Distribution System is that it "permits real-time exchange of essential tactical information--including user position location, identification, mission, and navigation data as well as target information . . ." (12:81).

The Integrated Electronic Warfare System's main advantage is identified in part of its name--integration. It "combines the functions of several different electronic warfare requirements, such as . . . active self protection, decoy, and expendable countermeasures dispensing" (17:44). Below, retired Admiral Julian Lake talks more about the positive aspects of integration:

> The main justification for Integrated Electronic Warfare System (INEWS) is integration, which is badly needed to increase [electronic warfare] effectiveness. Further, as long as the correct systems architecture is used, a modular INEWS configuration will greatly facilitate upgrading the various components . . . . [This is especially true for] the critical software configuration. (17:44-45)

The Integrated Electronic Warfare System is scheduled to be installed in the Air Force's Advanced Tactical Fighter.

Weapons Systems Testing

As previously stated, the Air Force does not have an integrated, open-air test capability for electronic combat weapons systems. Mr. George Nicholas, formerly the Assistant Director of Electronic Combat Systems at the Air

Force's Aeronautical Systems Division, gives this view of the situation:

> One reason for this [lack of an integrated test capability] is that the investments necessary to upgrade and modernize the nations's valuable [electronic combat] testing facilities to keep them abreast of the advancing threat have not been made. The end result is that we have fallen seriously behind in our ability to test, evaluate and measure the effectiveness of new systems . . . . (19:13)

The Electronic Combat Test Capability (ECTC) is a programmed response to this lack of an integrated test capability. Air Force thinking on this is stated in the Executive Overview of the ECTC Program.

> As a result of this widening gap between weapons systems performance and [electronic combat] test capability, the Air Force identified the need for a test range with resources capable of supporting realistic operational test and evaluation in electronic combat. The ECTC is a response to this need. (9:1)

The Electronic Combat Test Capability

The purpose of this section is to describe what the ECTC is. In doing so, the following areas will be addressed: 1) the ECTC operational concept; 2) the composition of the ECTC; and, 3) where it will be located and why.

The operational concept of the ECTC is fully described in the Electronic Combat Test Capability: Executive Overview, 15 April 1989. This excerpt captures the highlights of the concept.

The long-term [operational] goal of the ECTC is to provide a fully capable and flexible test environment able to adapt and respond to changing weapon system technology and threat capabilities. The immediate objective is to provide a realistic operational simulation of North Atlantic Treaty Organization (NATO) battlefield conditions with the flexibility to reconfigure the environment to represent other theaters of operations, including third-world scenarios. A comprehensive test and evaluation program for a complex, interactive [electronic combat] system involves a hierarchy of test methods. Each item of test data required is obtained through the most cost effective testing method that provides an acceptable level of confidence. It is important to operate new systems in as realistic an environment as possible to ensure that all relevant interactions are evaluated. Within this operational concept, ECTC will provide operationally meaningful information that cannot be obtained through other test methods and techniques.

The ECTC will be capable of providing high-fidelity simulations of threat environments representative of air/land battles, strategic air warfare, and special operations mission scenarios. This capability is primarily to support OT&E, but it is also suitable for certain developmental tests, joint testing, and exercises. The ECTC will provide benefits to other missions, such as tactics development, evaluation, and training. Range design and test support flexibility will allow the ECTC to accommodate other future test missions, including test requirements for all military services.

. . . The ECTC operational concept has been designed to provide the components that simulate the defense-in-depth of Soviet and Eastern European deployments. This provides the flexibility to handle changes in threat system and tactics or to simulate different battlefields, and also variations in test scenarios. The ECTC will provide an infrastructure that can be used in different ways by bringing in mobile and transportable threat systems. The current operational concept is to augment permanent assets by renting available threat systems from existing sources.

The infrastructure will include threat sites with electrical power and fiber-optic links for secure data collection and communications. Test data will be collected in a mission control center at Hill AFB. The

> threat sites will be spread across tactical, intermediate, and strategic test areas.
>
> . . . A key characteristic of operational realism, required to provide a true test of system responses to combat conditions, is the element of uncertainty. The ECTC will be able to vary test conditions to provide dynamic, interactive testing and keep participants from becoming too familiar with the test layout. This may involve changing mission profiles, tactics, types and employment of threats, deployments, force structures, and other parameters. (9:4-7)

As stated previously, the ECTC will be an integrated, open-air operational test capability. Various realistic test and exercise missions would be conducted on the ECTC. These missions and the assumptions made to formulate their profiles, participants, and flight times are discussed in Chapter IV.

The ECTC will replicate the electronic emissions of a Soviet integrated air defense system.

> The basic components of the ECTC are: 1) manned threat systems able to realistically represent the electronic environment of enemy radar systems, communications, passive detection systems, and jamming equipment; 2) a command, control, and communications overlay connecting these threat systems, which enables them to be operated as they would be by an enemy; 3) a controlled test area which allows both enemy ("red") and friendly ("blue") systems to free-space radiate during the course of EC tests; and, 4) sophisticated data collection instrumentation to provide time, space, position information and event parameters on both airborne and ground-based test components. (8:1-2)

The Air Force conducted a study to choose an existing range to base the ECTC. All current Department of Defense range and test facilities in the continental United States were initially evaluated (8:1-3). Most were discarded

because they did not meet minimum land and airspace requirements (8:1-3).

AFOTEC set up the following criteria to evaluate the remaining locations: 1) current mission compatibility with the ECTC; 2) capacity to accommodate ECTC mission requirements; 3) suitability to meet the technical and physical requirements of the ECTC; and, 4) the potential for impacting environmentally sensitive areas within each range (8:1-3). Based on the above criteria, eight areas were chosen for evaluation.

> These were: 1) the White Sands Missile Range/Fort Bliss/Holloman AFB complex in New Mexico and Texas; 2) the Tactical Fighter Weapons Center Nellis Range in Nevada; 3) the Southeastern Test and Training Area at Eglin AFB in Florida; 4) a complex including the Air Force Flight Test Center at Edwards AFB, the Naval Weapons Center China Lake, and Fort Irwin in California; 5) the Fallon Range in Nevada; 6) the Mountain Home AFB/Saylor Creek Range in Idaho; 7) the Goldwater Air Force Range/Yuma Proving Ground complex in Arizona; and 8) UTTR. (8:1-3)

After the area narrowing process was complete, UTTR was chosen because it was the only range that satisfied all the criteria.

> UTTR (Figure 1) is a major range and test facility base operated for the Department of Defense (DOD) by the AF Flight Test Center. The range consists of DOD-withdrawn land comprising over 900,000 acres and superimposed airspace within which flight tests can be conducted . . . . UTTR provides range facilities for all phases of test and evaluation of manned and unmanned aircraft systems and tactical training for air-to-air and air-to-ground weapons delivery for the DOD and other government agencies. UTTR is contained within the Great Salt Lake Desert, approximately 70 miles west of Salt Lake City, Utah. (8:1-3)

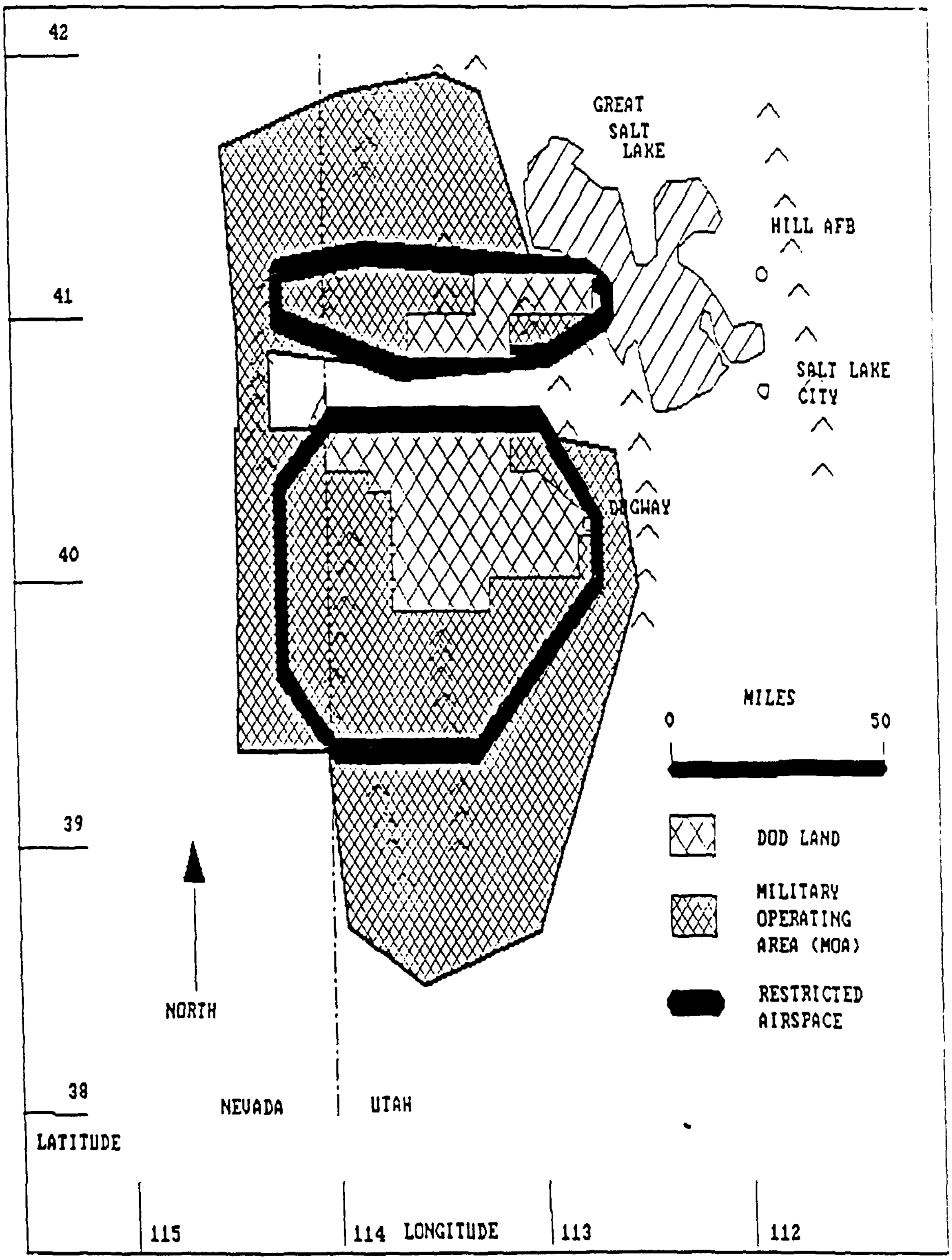

Fig. 1. Utah Test and Training Range

The 6545 Test Group, Hill AFB, Ogden, Utah, manages the UTTR. In their capacity as the range manager, the 6545 Test Group provides all test data gathering and breakdown, mission control, air combat maneuvering instrumentation, threat site operation and maintenance, and air traffic control.

The AF is considering several bases for staging (8). Each needs to be evaluated to see which base (or combination) offers the lowest cost from a life cycle perspective (recurring and nonrecurring costs) (5).

Capital Investment Evaluation Methods

Construction of the ECTC involves a large capital investment (exclusive of the ECTC threat simulation infrastructure) estimated to be \$99.5 to \$167.6 million (1). An aircraft base (or bases) must be chosen so that the aircraft that use the ECTC have a base from which to stage. This base requires investment for facilities, aircraft runway(s), air traffic control tower(s), fuel tanks, electrical lines, and water lines.

Choosing the lowest cost staging base involves making a capital budgeting decision. "Capital budgeting is the making of long-term planning decisions for investment . . ." (13:648). Why are capital budgeting decisions evaluated instead of just planned and made? Because capital budgeting

decisions are different from operating decisions in two ways:

> 1) . . . [C]apital expenditures are inherently future oriented in a way that current consumption expenditures or investments in working capital are not . . . [so that] their consequences have to be endured for a much longer period; and, 2) . . . capital expenditures are virtually irreversible, either because the asset acquired is inherently nontransferable, or because secondhand markets are such that the asset can be disposed of, if at all, only at an enormous sacrifice in price. (20:6)

Because of the above two characteristics, capital expenditures are strategic in nature and completely different than daily operating decisions (20:6).

Horngren, in his book Cost Accounting: A Managerial Emphasis, describes four ways to evaluate capital projects: 1) net present value; 2) internal rate of return; 3) payback; and, 4) accrual accounting rate of return (13:648). Quirin, in his book Analyzing Capital Expenditures: Private and Public Perspective, describes five ways to evaluate capital projects: 1) net present value; 2) terminal value; 3) internal rate of return; 4) payback; and, 5) [accrual] accounting rates of return (20:57-71).

The terminal value method is similar to the net present value method. The only difference is that under the terminal value method, the salvage (or terminal) value of the assets involved in the project are subtracted from the costs of the project at the end of the project's life (5:20).

The terminal value method also takes into account the time value of money (as does the net present value method), which is a central concern when evaluating capital projects. Discounted cash flows account for the time value of money by multiplying yearly net costs by the appropriate discount factors (5:9).

> The discounted cash-flow model . . . recognizes that the use of money has a cost [time value of money]. . . . The essence of discounted cash flow is to represent the cash inflows and outflows of a project at a common point in time so that they can be compared in an appropriate way. (13:649)

Each alternative's cash inflows and outflows are summed over the life cycle of the capital project and include all operating and investment (recurring and nonrecurring) costs (20:58). A comparison is made of the net present value cost of each alternative (5:24).

The Air Force subscribes to the net present value model of evaluating capital projects (5). The net present value model is also referred to as the discounted cash-flow model. Horngren states that "[b]ecause the discounted cash-flow model explicitly and routinely weighs the time value of money, it is usually the best model to use for long-range decisions" (13:649).

Summary

Electronic combat had its start at the turn of the 20th century and is now an integral part of modern warfare. It

was used recently by the United States in the 1986 air raid of Libya. The Department of Defense has institutionalized the importance of electronic combat planning by organizing the Joint Electronic Warfare Center. The Air Force realizes that electronic combat employment coordination is a full-time job so it has established the position of Electronic Combat Coordination Officer at wing level.

The demand for new electronic combat technologies is evident with the development of new weapons systems that will have a major impact on the Air Force's war fighting capabilities.

Air Force officials realize there is a need for a simulated electronic combat capability for testing and training. To meet this need, the Air Force is programming for an ECTC. This open-air capability will allow the Air Force to test electronic combat systems in a realistic operational environment, as well as to train pilots under realistic combat conditions.

The Air Force requires research and analysis to develop the lowest cost implementation plan for the ECTC. A complete analysis of the costs of the various aircraft staging options will allow decision makers to more confidently evaluate the ECTC. Chances of the ECTC receiving funding by Congress will improve if the lowest cost way is found to field it.

Proposed capital projects like the ECTC need to be evaluated separately from pure operating expense considerations. The net present value method of evaluating capital projects incorporates the major financial methods required by the AF and is recognized as the superior evaluation method.

III. Methodology

Cost Analysis (CA) Methodology

The Air Force Operational Test and Evaluation Center (AFOTEC) is the AF agency that has programming responsibility for the ECTC. The CA is a major input to the ECTC programming effort. The data to accomplish the CA was obtained from AFOTEC. The CA evaluates each alternative from a 25-year life cycle cost perspective. The CA is different from an economic analysis only in that each alternative's benefits are not listed or evaluated. This is because the benefits are judged by AFOTEC to be equivalent among the alternatives.

At a minimum, in accordance with AFR 173-15, Economic Analysis and Program Evaluation for Resource Management, and in compliance with contemporary capital project evaluation, the CA model incorporates four financial methods. The four methods, which are identified by asterisk below, conveniently break down into the following four phases of data gathering and manipulation:

*1) Categorization of nonrecurring and recurring costs for each alternative.

A) The nonrecurring costs were calculated by accomplishing the following steps:

1) Calculate and sum the total cost of all facilities.

2) Calculate all other nonrecurring costs. These costs are for runways, air traffic control towers, fuel tanks, electrical lines, and water lines.

B) The recurring costs were calculated. There are two main categories of recurring costs for this CA. The first is the flying hour cost (FHC) input. The second is all other recurring costs.

1) The following was accomplished to calculate the FHC:

a) Project ECTC test mission workload for 25 years for all ECTC use categories.

b) Identify the types of aircraft (aircraft categories) to be used in each ECTC use category.

c) Identify the number of aircraft, by aircraft category, for the ECTC missions.

d) Calculate the actual FHC for each type of aircraft that will be used so that the total FHC can be summed. These individual FHCs were taken from AFR 173-13, <u>AF Cost and Planning Factors</u>.

e) Calculate the transit time based on flight distance from each alternative location to the ECTC (ingress and egress time).

f) Calculate the amount of time each aircraft will spend on the ECTC (on-range time).

g) Sum the transit and on-range times (total mission time).

h) Calculate the costs of a, c, d, and g above for each fiscal year, to obtain the FHC input for each alternative. This calculation is described further in Chapter IV under "General Cost Algorithm."

2) The following was accomplished to calculate all other recurring costs:

a) Utility usage and maintenance costs for each alternative were calculated based on the square footage of each facility. These costs were calculated using local cost factors obtained from the 6545 Test Group's Civil Engineering Branch.

b) Personnel costs were calculated for each alternative. The cost of these personnel were calculated using AFR 173-13.

*2) The cash flows were discounted to account for the time value of money of each alternative; this gave the total present value cost of each alternative. The product of each year's total cost and the applicable discount factor gives the yearly present value cost. This was accomplished by using mid-year discount factors from AFR 173-13. The terminal value of facilities (as discussed below) was

subtracted from the total present value to arrive at the total net present value cost for each alternative.

*3) The straight line depreciation method was used to take into account the use of assets, and to arrive at the terminal value for each alternative's facilities. This was done in accordance with AFR 173-15.

*4) After all the costs were calculated, the total net present value cost of each alternative was compared to see which was the lowest cost alternative. Electronic spreadsheets were developed to do this.

The CA results are presented in Chapter V.

Research Scope

All the costs unique to each aircraft staging alternative were used in the CA as well as the common costs. This is done so that the total cost of operating each alternative staging base could be documented. The only costs left out of the CA, which are common to each alternative, are the costs of the electronic threat simulation equipment.

As stated previously, 25 years of mission workload data is used for the FHC input. This mission workload estimate is comprised of inputs from all intended users of the ECTC and is described entirely in Chapter IV.

Research Assumptions

There are two categories of assumptions for the CA. Assumptions of the first category are for the mission workload input used in the FHC input, and assumptions of the second category deal with the actual financial methods of the CA. The workload assumptions are for the number of missions, aircraft categories, participants per mission by aircraft category, and the percentage of missions requiring refueling. They are described in the next chapter.

The CA financial methods assumptions are for the project life cycle, discount rates, depreciation, and inflation rates, and are presented in Chapter V.

This chapter has described the cost analysis methodology, the research scope, and the research assumptions. A more detailed explanation of the assumptions and the general cost algorithm is presented in Chapter IV.

IV. Workload Formulation and Assumptions

Essential to the CA is the workload used in the determination of the total flying hour costs for each basing alternative. This chapter describes the ECTC planning structure AFOTEC used and the process AFOTEC followed to formulate the ECTC mission workload. It also presents the general cost algorithm that was developed to calculate the costs of the FHC input for the ECTC use categories. Each element of this cost algorithm is discussed and, where appropriate, background information is given concerning each element's development. Finally, Figure 4a-4d, which contains the mission workload data that the CA is based on, is explained.

This chapter was developed with the assistance of Lt Col Robert Greenlee who is Deputy Director of Resource Management at AFOTEC.

ECTC Planning Structure

Recall that the CA is based on nonrecurring and recurring costs. The recurring costs are comprised of the FHC input and all other recurring costs as detailed in Chapter III. The most controversial part of recurring cost is the FHC input because it relies on projected mission workload. Because of the importance of the FHC input, test and evaluation managers from AFOTEC's Test and Evaluation

Directorate and test representatives from Tactical Air Command (TAC), Strategic Air Command (SAC), Military Airlift Command (MAC), and AF Systems Command (AFSC) were involved in the FHC planning and formulation process (as well as in other ECTC-related programming efforts). This ECTC planning process was formalized and organized through a structure called the ECTC Planning Board. The ECTC Planning Board is overseen by the General Officer Steering Group. The General Officer Steering Group membership is comprised of general officers from all participating MAJCOMs, air staff organizations, and U.S. Army and Navy test organizations. Through this Board structure, consensus was reached on mission workload, participants, and the types of aircraft projected to use the ECTC.

General Cost Algorithm

The following is the general cost algorithm developed to cost the FHC input for each of the alternative basing options, for each fiscal year (FY 1991 through FY 2015).

$$\sum_{i=1}^{13} \sum_{j=1}^{17} \sum_{k=1}^{4} \sum_{l=1}^{9} (W_i * X_{ijk} * Y_{il} * Z_j) = \mathit{FHC}$$

where:
- **W** = the number of missions.
- **X** = the number of each type of aircraft.
- **Y** = total mission time (ingress time + range time + egress time).
- **Z** = cost by hour, by aircraft type.
- i = the mission category type (1 . . 13).
- j = the aircraft type (1 . . 17).

k = the aircraft category (1 . . 4).
l = the staging location (1 . . 9).

The following describes how each element in the general cost algorithm was developed/formulated.

Cost Algorithm Element W

This element specifies the number of missions for each of 13 mission categories. The numbers were derived by the ECTC planning board for each category, by fiscal year.

An early test capability was to be in place by the end of FY 91 to be used from FY 91-93. This analysis assumes that limited mission use of the ECTC will begin in FY 91. Mission usage will increase substantially in FY 94 when intermediate capability is achieved. Intermediate capability will be used from FY 94-99. Most of the 13 ECTC use categories will commence ECTC operations at this time. The ECTC will achieve full capability by FY 2000. Full capability is when all ECTC electronic simulation equipment is in place. The phased increase in the simulation capability of the ECTC is the reason why the level of ECTC missions increase from FY 91 thru FY 2000 as depicted in Figure 4a-4d. The incremental buildup in the number of missions programmed for the ECTC, as described above, is outlined in Electronic Combat Test Capability at the Utah Test and Training Range: Description of Proposed Action and Alternatives (DOPAA), dated January, 1990.

Cost Algorithm Element X

This element specifies the number of aircraft for each type of four aircraft categories: blue force (B), red force (R), airborne warning and control aircraft (AW), and airborne interceptor (AI). The number of blue aircraft participants per mission were decided upon after deliberations by the ECTC planning board. Overall, past test, training, and exercise scenarios were used to decide on participant levels for each ECTC use category. Additionally, participant levels were also estimated based on the relative level of ECTC electronic simulation equipment that would be available in each FY (as described previously).

Many of the ECTC use categories require an airborne adversary or red force to participate in test, training, or exercise mission scenarios. The assumptions on the composition of this force and the frequency of its use are different depending on the ECTC use category. In general, the red force consists of a varying number of fighter type aircraft, simulating the presence and tactical response of an opposing fighter or interceptor force. Historically, testing and training have not always simulated a red force and this is accounted for by a percentage simulated entry.

An airborne warning and control system aircraft is used to simulate the presence (and eventually the electronic

response) of a Soviet AWACS threat. Additionally, an airborne interceptor simulator is used to electronically simulate an AI threat. There are seventeen different types of aircraft that were used in the CA for costing purposes. These aircraft were used for the 13 different ECTC use categories as specified in the DOPAA. The aircraft used are as follows: F-15C/D/E, F-16A/B, ATF, F-111B, EF-111, B-1B, B-2, C-141B, C-17A, KC-135, C-130H, AC-130, E-3B, and RF-4C.

The specific aircraft used are mission and year dependent. In general, the aircraft are varied to reflect the projected development of new aircraft, and when these aircraft would undergo testing. For example, for AFOTEC tactical OT&E, the flying hour cost of an F-15C is used for the blue aircraft for costing purposes between FY 91-96. After FY 96, the ATF is used in this category for blue aircraft.

These different participants can be seen in Figure 4a-4d, and are depicted by the alphabetical designators described above. The number next to the alphabetical designator tells how many of each type of aircraft are used for each mission. An example of the interpretation of Figure 4a-4d is presented at the end of this chapter.

Cost Algorithm Element Y

The total mission time (Y) is equal to the time it takes to ingress to the range, the on-range mission time, and the

time it takes to egress and return to base. This total mission time is different depending on the type of mission (tactical or strategic). Median cruise speeds of 325 knots true airspeed (KTAS) for strategic aircraft and 375 KTAS for tactical aircraft were used to determine flight time for the ingress and egress portions of the missions. The on-range portion of the total mission time was determined by the time it would take to accomplish a test or exercise objective for the particular ECTC use category. The ingress and egress portions of the mission time were calculated based on these aircraft speeds, and on mission planning map plots (flight profiles) of the actual air routes that would be flown by ECTC aircraft originating from the combination of the nine staging bases considered for the six alternatives evaluated in this analysis. As stated above, total mission time was then arrived at by adding the on-range portion of the mission to the ingress and egress times.

The missions performed on the ECTC will require a variety of flight profiles and there is a risk inherent in attempting to standardize them. However, from a cost analysis point of view, the risk is minimal: some profiles may be longer than assumed and others shorter, but the profiles that are used are typical of much of the test and exercise flight activity that will characterize the ECTC's usage.

The flight profiles developed were driven by three factors: 1) location of the staging bases; 2) location and orientation of the ECTC ground space; and, 3) fuel conservation.

The ECTC will be implemented with the "Forward Line of Troops" simulation (identified as the TTA or tactical target area) in the south UTTR range area and the Strategic Threat Area (STA) simulation in the mid-range area as shown in Figure 2. The TTA and the STA are the electronic threat simulation of a Soviet integrated air defense sector referred to previously.

On a typical ECTC test or exercise mission, the blue force will launch, cruise to an entry point south of the range, go low-level and ingress a low-level corridor into the TTA, engage and transit the TTA, engage and transit the STA, return through the south entry point and recover. The red force would launch, cruise to an entry point at the north end of the combat arena, go low-level, engage the blue force and transit the STA and intermediate areas, return to the north entry point and recover. A notional depiction of this mission scenario for tactical test or exercise missions is shown in Figure 3.

Cost Element Z

This element is the dollar cost per flying hour for each aircraft type. This value is derived from AFR 173-13, as

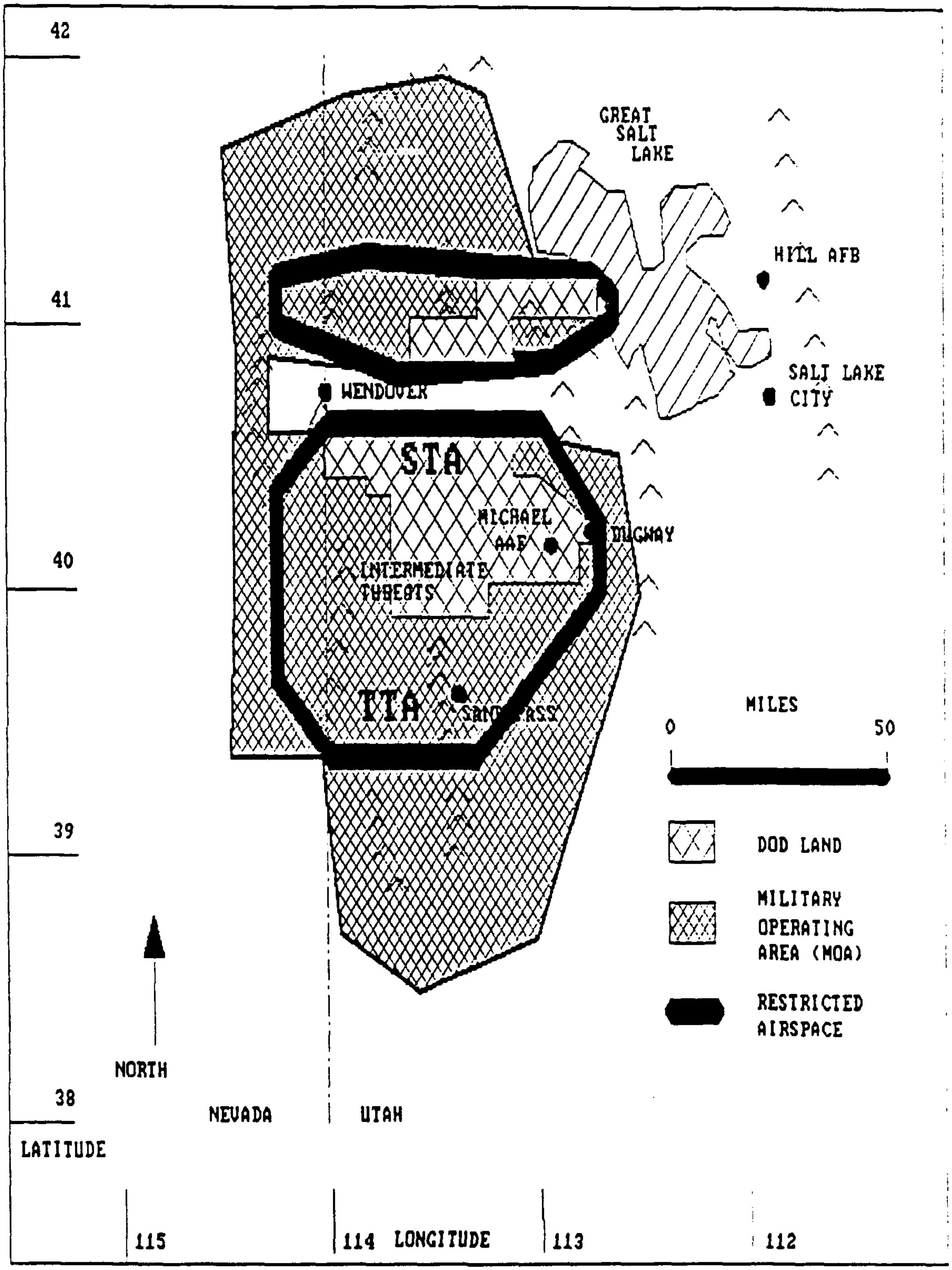

Fig. 2. Proposed Operational Areas

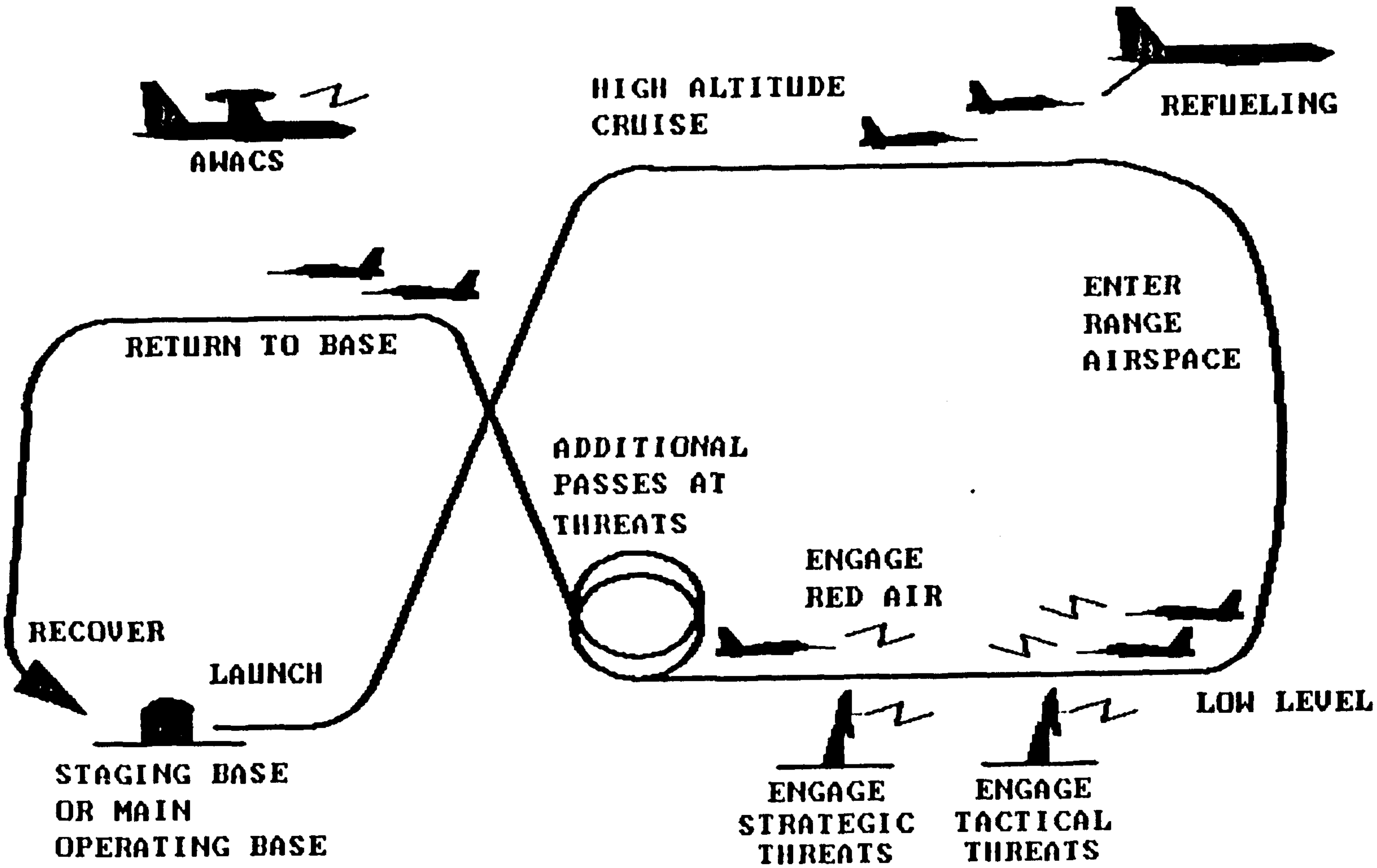

Fig 3. Notional ECTC Mission Profile

found on the Air Force Cost Center's Electronic Bulletin Board.

General Cost Algorithm Summary

The flying hour cost (**FHC**) by fiscal year, is equal to the **product** of the number of missions for each ECTC use category ($\mathbf{W}_i$), the number of each type of aircraft by mission category, aircraft type, and aircraft category ($\mathbf{X}_{ijk}$), the total mission time, by mission category and staging location ($\mathbf{Y}_{il}$), and the cost by hour, by aircraft type ($\mathbf{Z}_j$).

The total FHC are summed by fiscal year to arrive at the flying hour cost for each alternative.

Interpretation of Figure 4a-4d

Many assumptions were made to execute this CA. These assumptions are based on the planning process discussed previously. These assumptions have been accepted by the ECTC Planning Board.

The general classes of assumptions are for the following 13 ECTC use categories: 1) AFOTEC-conducted tactical operational test and evaluation (OT&E); 2) AFOTEC-conducted strategic OT&E, 3) TAC-conducted OT&E; 4) TAC tactics development and evaluation (TD&E); 5) TAC training; 6) SAC-conducted OT&E; 7) SAC TD&E; 8) SAC training; 9) MAC-

MISSION CATEGORY	RANGE MISSION TIME (HOURS)	1991 MSSN	1991 SORTIES/ MSSN	1992 MSSN	1992 SORTIES/ MSSN	1993 MSSN	1993 SORTIES/ MSSN	1994 MSSN	1994 SORTIES/ MSSN	1995 MSSN	1995 SORTIES/ MSSN	REFUEL RQMTS % MSSNS
AFOTEC OT&E, TACTICAL PROGRAMS	1	30	2 B	60	2 B 1 R (25%)	60	2 B 1 R (25%)	90	2 B 2 R (40%) 1 AW(10%)	135	2 B 2 R (40%) 1 AW(10%)	20% SEE NOTES 2 & 3
AFOTEC OT&E, STRATEGIC/ SPEC OPS	3	0	0 0	0	0 0	30	2 B 1 R (25%)	60	1 B 2 R (25%)	90	1 B 2 R (25%)	0
TAC OT&E	1	0	0 0	0	0 0	0	0 0	200	1 B	200	1 B	20% SEE NOTES 2 & 3
TAC TD&E	1	0	0 0	0	0 0	0	0 0	100	1 B 2 R	100	2 B 4 R	20% SEE NOTES 2 & 3
TAC TRAINING	1	20	4 B/R	50	4 B 2 R	75	4 B 2 R	200	4 B 2 R	200	4 B 2 R	0
SAC OT&E (NOTE 1)	3	0	0 0	6	1 B 4 R(40%) 1 AW(40%)	12	1 B 4 R(40%) 1 AW(40%)	24	1 B 4 R(40%) 1 AW(40%)	24	1 B 4 R(40%) 1 AW(40%)	0

Fig. 4a. ECTC Workload Numbers: Part 1

MISSION CATEGORY	RANGE MISSION TIME (HOURS)	1996 MSSN	1996 SORTIES/ MSSN	1997 MSSN	1997 SORTIES/ MSSN	1998 MSSN	1998 SORTIES/ MSSN	1999 MSSN	1999 SORTIES/ MSSN	2000 MSSN	2000 SORTIES/ MSSN	REFUEL RQMTS % MSSNS
AFOTEC OT&E, TACTICAL PROGRAMS	1	150	2 B 4 R(40%) 1 AW(20%)	150	2 B 4 R(40%) 1 AW(20%)	165	2 B 4 R(40%) 1 AW(20%) 1 AI(20%)	165	2 B 4 R(40%) 1 AW(20%) 1 AI(20%)	180	2 B 4 R(40%) 8 R(10%) 1 AW(50%) 1 AI(50%)	20% SEE NOTES 2 & 3
AFOTEC OT&E, STRATEGIC SPEC OPS	3	105	2 B 4 R(50%) 1 AW(50%)	105	2 B 4 R(50%) 1 AW(50%)	120	2 B 4 R(50%) 1 AW(50%) 1 AI(50%)	120	2 B 4 R(50%) 1 AW(50%) 1 AI(50%)	135	2 B 4 R(50%) 1 AW(50%) 1 AI(50%)	0
TAC OT&E	1	140	2 B 0 0	160	2 B 0 0	200	2 B 2 R(30%) 1 AW(30%) 1 AI(30%)	200	2 B 4 R(30%) 1 AW(30%) 1 AI(30%)	200	2 B 4 R(60%) 1 AW(60%) 1 AI(60%)	20% SEE NOTES 2 & 3
TAC TD&E	1	100	2 B 4 R	100	2 B 4 R	100	2 B 4 R	100	2 B 4 R	100	2 B 4 R	20% SEE NOTES 2 & 3
TAC TRAINING	1	200	4 B 2 R	200	4 B 2 R	200	4 B 2 R	200	4 B 2 R	200	4 B 2 R	0
SAC OT&E (NOTE 1)	3	30	1 B 4 R(40%) 1 AW(40%)	36	1 B 4 R(40%) 1 AW(40%)	36	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	40	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	50	2 B 4 R(40%) 1 AW(40%) 1 AI(40%)	0

Fig. 4b. ECTC Workload Numbers: Part 2

MISSION CATEGORY	RANGE MISSION TIME (HOURS)	1991 MSSN	1991 SORTIES/ MSSN	1992 MSSN	1992 SORTIES/ MSSN	1993 MSSN	1993 SORTIES/ MSSN	1994 MSSN	1994 SORTIES/ MSSN	1995 MSSN	1995 SORTIES/ MSSN	REFUEL RQMTS % MSSNS
SAC TD&E	3	0	0 0	0	0 0	0	0 0	24	1 B 4 R(40%) 1 AW(40%)	24	1 B 4 R(40%) 1 AW(40%)	0
SAC TRAINING	2	0	0 0	0	0 0	0	0 0	6	1 B 4 R(40%) 1 AW(40%)	6	1 B 4 R(40%) 1 AW(40%)	0
MAC OT&E (NOTE 1)	3	20	4 B 4 R	20	4 B 4 R	20	4 B 4 R	11	2 B 1 R	15	2 B 1 R	0
MAC TD&E	4	1	2 B	1	2 B	1	2 B	1	2 B	2	3 B 1 R	30% SEE NOTES 2 & 3
MAC TRAINING	4	2	3 B 1 R	2	3 B 1 R	2	3 B 1 R	2	3 B 1 R	4	6 B 2 R	30% SEE NOTES 2 & 3
AFSC DT&E	1	0	0 0	0	0 0	0	0 0	50	2 B	100	2 B	20% SEE NOTES 3 & 4
JOINT TESTS & EXERCISES	1.5	0	0 0	0	0 0	0	0 0	200	6 B 4 R	200	6 B 4 R	20% SEE NOTE 4

Fig. 4c. ECTC Workload Numbers: Part 3

MISSION CATEGORY	RANGE MISSION TIME (HOURS)	1996 MSSN	1996 SORTIES/ MSSN	1997 MSSN	1997 SORTIES/ MSSN	1998 MSSN	1998 SORTIES/ MSSN	1999 MSSN	1999 SORTIES/ MSSN	2000 MSSN	2000 SORTIES/ MSSN	REFUEL RQMTS % MSSNS
SAC TD&E	3	24	1 B 4 R(40%) 1 AW(40%)	24	1 B 4 R(40%) 1 AW(40%)	24	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	24	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	24	2 B 4 R(40%) 1 AW(40%) 1 AI(40%)	0
SAC TRAINING	2	12	1 B 4 R(40%) 1 AW(40%)	12	1 B 4 R(40%) 1 AW(40%)	16	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	16	1 B 4 R(40%) 1 AW(40%) 1 AI(40%)	16	2 B 4 R(40%) 1 AW(40%) 1 AI(40%)	0
MAC OT&E (NOTE 1)	3	15	2 B 1 R	15	2 B 1 R	15	2 B 1 R	15	2 B 1 R	15	2 B 2 R(60%) 1 AW(60%) 1 AI(60%)	0
MAC TD&E	4	2	3 B 1 R	2	3 B 1 R	2	3 B 1 R	2	3 B 1 R	2	3 B 1 R	30% SEE NOTES 2 & 3
MAC TRAINING	4	4	6 B 2 R	4	6 B 2 R	4	6 B 2 R	4	6 B 2 R	4	6 B 2 R	30% SEE NOTES 2 & 3
AFSC DT&E	1	150	2 B	200	2 B	250	2 B	300	2 B	400	2 B	20% SEE NOTES 2 & 3
JOINT TESTS & EXERCISES	1.5	200	6 B 4 R	200	6 B 4 R	200	6 B 4 R	200	6 B 4 R	200	6 B 4 R	20% SEE NOTE 4

Fig. 4d. ECTC Workload Numbers: Part 4

conducted OT&E; 10) MAC TD&E; 11) MAC training; 12) AFSC development test and evaluation (DT&E); and, 13) exercises.

Figure 4a-4d presents the actual number and types of missions used in the CA. These are the numbers (excluding the aircraft flying hour cost and the flying times from the nine staging locations) that were used in the general cost algorithm. In Figure 4a-4d, each use category is described by fiscal year beginning in FY 91 and ending in FY 2000. Each fiscal year is broken down by number of missions, the categories of aircraft participating on each mission, and the number within each aircraft category that participate. For this CA, all numbers used in FY 2000 were held constant and extrapolated for FYs 2001 through FY 2015.

All the flying hour assumptions used in this analysis, as documented in Figure 4, are also described in the DOPAA (which was referred to previously) prepared for the ECTC programming process.

> [The] DOPAA . . . identifies proposed and alternative locations for ECTC components at UTTR and describes facilities, infrastructure, and operational [(flying)] activities associated with the ECTC. The DOPAA is based on Air Force and other agency planning for this activity. [AFOTEC] prepared this document in accordance with Air Force Regulation 19-2, Environmental Impact Analysis Process, dated 10 August 1982. (8:i)

The first column of Figure 4a-4d lists the 13 ECTC use categories. To understand how to read Figure 4, the AFOTEC-

conducted tactical OT&E row is described here. All the other categories can be read and understood in the same way.

The figures contain flying hour data for FY 91 (first column, Figure 4a) through FY 2000 (second to the last column, Figure 4b). Under each FY column, there are two additional subcolumns for missions and sorties/missions. Additional data provided in the sorties/mission column are the aircraft category (e.g., R for red force, and B for blue force) and the percentage (%) of the missions that these aircraft will participate.

The number found in the missions column, in this case "30", is simply the number of AFOTEC-conducted Tactical OT&E missions that will use the ECTC in FY 91.

The number found in the sorties/mission column, in this case "2", is the number of aircraft that will participate on each mission. There is also a letter in this column. In this case, the letter is "B" which designates that the sorties will be blue or friendly aircraft.

If no percentage appears, as is the case here, 100% of the missions listed in the missions column will have 2 blue aircraft assigned to them.

Refer to the FY 2000 column within the AFOTEC-conducted tactical OT&E category on the second page (4b) of Figure 4. Using the same logic described above, there will be 180 missions containing 2 blue aircraft for 100% of the missions

(designated by the "180 2 B"). Additionally, looking below the "180 2 B" line, for 40% of the 180 missions, 4 aggressor or red (R) aircraft will participate; for 10% of the 180 missions, 8 aggressor aircraft will participate; for 50% of the 180 missions, 1 airborne warning and control (AW) aircraft will participate; and, for 50% of the 180 missions, 1 airborne intercept (AI) simulation aircraft will participate.

Scanning across Figure 4a-4d, one can generally see that the number of missions and participants increase from FY 91 to FY 2000. This reflects the increase in the ECTC simulation capability described previously. FY 2000 mission and participant levels are held constant from FY 2000 to FY 2015. FY 2015 is the last year to be included in the analysis.

Refer to the last column in Figure 4a-4d which lists the refueling requirements by category. The categories that have a refueling requirement have a number in them. For AFOTEC-conducted tactical OT&E, 20% of the missions require refueling. For refueled missions, 0.3 hours are added to blue sortie lengths to allow for time on the refueling boom and transit time to/from a refueling track. AFOTEC assumed all tanker sorties at 4.0 hours for costing purposes. For these categories, one tanker per range mission was assumed. For the Joint Tests and Exercises category, equal refueling

requirements for the red and blue forces is assumed as well as two tankers per range mission. This is because the red and blue aircraft are airborne for approximately equal lengths of time.

General Cost Algorithm Example

The following is an example of the use of the general cost algorithm with the numbers found in ECTC use category AFOTEC tactical OT&E, FY 91 (Figure 4a). Recall the general cost algorithm.

$$\sum_{i=1}^{13} \sum_{j=1}^{17} \sum_{k=1}^{4} \sum_{l=1}^{9} (W_i * X_{ijk} * Y_{il} * Z_j) = FHC$$

W_i equals 30. X_{ijk} equals 2; this is the number of blue aircraft on each mission. Y_{il} is the mission time for a tactical mission from the appropriate staging location: for this example, the tactical mission time from Hill AFB of 1.99 hours is used. Z_j equals $ 3,831; this is the flying hour cost for an F-15C. The **FHC** equals 30 * 2 * 1.99 * $ 3,831 = $ 457,421. For each alternative the summation of these calculations, as described previously, equals the FHC for that alternative.

V. Cost Analysis (CA) Alternatives Evaluated, Financial Method Assumptions and Procedures, and Financial Results

This chapter is divided into three sections. The first presents the alternatives evaluated in the CA. The second is a listing of the financial method assumptions that were made performing the CA. The final section is a presentation of the CA financial results. In this chapter, net present value and discounted cost are used interchangeably and refer to the same thing.

CA Alternatives Evaluated

Six staging base alternatives were evaluated in the CA. These staging base alternatives were evaluated as directed by the DOPAA (8). The six alternatives evaluated are listed below.

1) staging from Hill AFB, Utah;

2) staging from Michael AAF at Dugway Proving Ground, Utah;

3) staging from Salt Lake International Airport, Utah;

4) staging from Wendover Auxiliary Airfield, Utah;

5) staging from Delta Municipal Airport, Utah;

6) staging from remote bases; a combination of Nellis AFB (for tactical missions) and Ellsworth AFB/Dyess AFB/McChord AFB (for strategic missions) was used for costing purposes.

The implementation of any of the above alternatives entails some percentage of staging from Michael AAF and Hill AFB. Under each of the above alternatives, the base or airport that designates the alternative is the main staging base for that alternative.

The percentages of sorties originating from the bases under each alternative were taken from the DOPAA.

Financial Method Assumptions and Procedures

The following financial method assumptions were made for this CA:

1) A 25 year life cycle was used for each alternative.

2) The present value of the cash flows was taken into account by using 10%, mid-year discount factors. The Air Force specifies using 10% as the discount rate for CAs (6).

3) At the end of the 25 year life cycle, the depreciated value of the facilities in each alternative is subtracted from the total present value cost of that respective alternative. This subtraction is done to arrive at the total net present value cost of each alternative. Consistent with Air Force policy, all facilities are depreciated at an annual rate of 1.7%.

4) All costs are in 1990 constant dollars.

5) The inflation rate is assumed to be constant across all categories of cost. Therefore, costs were not escalated.

The following financial procedures were used to accomplish this CA:

1) The CA was accomplished in accordance with AFR 173-15, Economic Analysis and Program Evaluation for Resource Management, March 1988.

2) All cost factors used in the CA were taken from AFR 173-13, USAF Cost and Planning Factors, September 1986, with updates provided by the Air Force Cost Center's Electronic Bulletin Board.

CA Financial Results

The following are the financial results of the CA. For each alternative, the total net project cost (discounted) and the uniform annual cost is listed. The total net project cost represents the present value (PV) cost of implementing each alternative. The uniform annual cost is a way of displaying the average yearly present value cost. The alternatives are displayed in ascending cost order.

Rank	Staging Alternative	Total Net PV Project Cost	Uniform Annual Cost	Figure Number
1	Remote	$ 691,089,498	$ 66,097,313	5.a
2	Delta	703,239,440	67,593,231	5.b
3	Wendover	713,831,868	68,562,408	5.c
4	Salt Lake IAP	747,791,390	71,660,156	5.d
5	Hill AFB	750,780,972	71,843,777	5.e
6	Michael AAF	758,244,236	72,672,371	5.f

The total net present value costs presented for each alternative can be found on the bottom of each referenced figure by the exact title they are referred to above. In present value terms, the Remote basing alternative was the lowest cost staging option. The flying hour costs for the Remote alternative were the most expensive because the flying distances to the ECTC were the longest of the six alternatives. But the added flying hour costs of the Remote alternative were offset by the large investment for facilities and infrastructure of the other alternatives. This large investment made the other alternatives more expensive than the Remote alternative.

The following are the constant dollar results displayed in FY 1990 dollars. The alternatives are displayed in ascending cost order.

Project Title: ECTC
Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE
Discount Rate: 0.1
Alternative: PRIMARY STAGING FROM REMOTE BASES
Economic Life (in years): 25
Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

PROJECT PERIOD	FISCAL YEAR	NON-RECURRING Invstmnt	RECURRING Non-Energy Costs	RECURRING Energy Costs	Total Annual Costs	Disc Factor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6630098	0	12130098	0.8668	10514177
3	1993	8420000	15196609	0	23616609	0.7880	18609548
4	1994	7280000	44834901	0	52114901	0.7164	37332538
5	1995	10000000	53447530	0	63447530	0.6512	41318794
6	1996	20500000	71528355	0	92028355	0.5920	54483110
7	1997	4160000	73675673	0	77835673	0.5382	41891531
8	1998	31140000	83794699	0	114934699	0.4893	56234913
9	1999	0	91663309	0	91663309	0.4448	40771596
10	2000	0	108796439	0	108796439	0.4044	43993060
11	2001	0	108796439	0	108796439	0.3676	39993691
12	2002	0	108796439	0	108796439	0.3342	36357901
13	2003	0	108796439	0	108796439	0.3038	33052637
14	2004	0	108796439	0	108796439	0.2762	30047852
15	2005	0	108796439	0	108796439	0.2511	27316229
16	2006	0	108796439	0	108796439	0.2283	24832936
17	2007	0	108796439	0	108796439	0.2075	22575396
18	2008	0	108796439	0	108796439	0.1886	20523087
19	2009	0	108796439	0	108796439	0.1715	18657352
20	2010	0	108796439	0	108796439	0.1559	16961229
21	2011	0	108796439	0	108796439	0.1417	15419299
22	2012	0	108796439	0	108796439	0.1288	14017545
23	2013	0	108796439	0	108796439	0.1171	12743222
24	2014	0	108796439	0	108796439	0.1065	11584748
25	2015	0	108796439	0	108796439	0.0968	10531589
1)TOTALS:		99500000	2185359922	0	2284859922	10.520079	695349015.38

2)Total Project Cost (discounted):--- 695349015
3)Less Terminal Value (discounted):--- 4259517
4)Total Net Project Cost (discounted):-- 691089498
5) Uniform Annual Cost:--- 66097313

Fig. 5a. Remote Alternative Costs

Project Title: ECTC

Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE

Discount Rate: 0.1

Alternative: PRIMARY STAGING FROM DELTA

Economic Life (in years): 25

Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

PROJECT PERIOD	FISCAL YEAR	NON-RECURRING Invstmnt	RECURRING Non-Energy Costs	RECURRING Energy Costs	Total Annual Costs	Disc Factor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6709545	0	12209545	0.8668	10583040
3	1993	8420000	16101637	0	24521637	0.7880	19322697
4	1994	37780000	46884363	0	84664363	0.7164	60649363
5	1995	25470000	55508618	0	80978618	0.6512	52735525
6	1996	39200000	78757251	0	117957251	0.5920	69833671
7	1997	1420000	83228691	0	84648691	0.5382	45558330
8	1998	37340000	95163435	0	132503435	0.4893	64830892
9	1999	0	83959368	0	83959368	0.4448	37344903
10	2000	0	96162678	0	96162678	0.4044	38884457
11	2001	0	96162678	0	96162678	0.3676	35349507
12	2002	0	96162678	0	96162678	0.3342	32135915
13	2003	0	96162678	0	96162678	0.3038	29214468
14	2004	0	96162678	0	96162678	0.2762	26558607
15	2005	0	96162678	0	96162678	0.2511	24144189
16	2006	0	96162678	0	96162678	0.2283	21949262
17	2007	0	96162678	0	96162678	0.2075	19953875
18	2008	0	96162678	0	96162678	0.1886	18139886
19	2009	0	96162678	0	96162678	0.1715	16490806
20	2010	0	96162678	0	96162678	0.1559	14991642
21	2011	0	96162678	0	96162678	0.1417	13628765
22	2012	0	96162678	0	96162678	0.1288	12389786
23	2013	0	96162678	0	96162678	0.1171	11263442
24	2014	0	96162678	0	96162678	0.1065	10239493
25	2015	0	96162678	0	96162678	0.0968	9308630
1)TOTALS:		167630000	2008761480	0	2176391480	10.520079	711086188.77

2)Total Project Cost (discounted):-- 711086189

3)Less Terminal Value (discounted):--- 7846749

4)Total Net Project Cost (discounted):--------------------------------------- 703239440

5)Uniform Annual Cost:-- 67593231

Fig. 5b. Delta, UT Alternative Costs

Project Title: ECTC
Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE
Discount Rate: 0.1
Alternative: PRIMARY STAGING FROM WENDOVER
Economic Life (in years): 25
Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

	PROJECT PERIOD FISCAL YEAR	NON-RECURRING Invstmnt	RECURRING Non-Energy Costs	RECURRING Energy Costs	Total Annual Costs	Disc Factor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6709545	0	12209545	0.8668	10583040
3	1993	8420000	16101637	0	24521637	0.7880	19322697
4	1994	37780000	46884363	0	84664363	0.7164	60649363
5	1995	25470000	55508618	0	80978618	0.6512	52735525
6	1996	38240000	78714591	0	116954591	0.5920	69240071
7	1997	1420000	83238133	0	84658133	0.5382	45563411
8	1998	37340000	95174754	0	132514754	0.4893	64836430
9	1999	0	86286962	0	86286962	0.4448	38380211
10	2000	0	98962561	0	98962561	0.4044	40016621
11	2001	0	98962561	0	98962561	0.3676	36378747
12	2002	0	98962561	0	98962561	0.3342	33071588
13	2003	0	98962561	0	98962561	0.3038	30065080
14	2004	0	98962561	0	98962561	0.2762	27331891
15	2005	0	98962561	0	98962561	0.2511	24847173
16	2006	0	98962561	0	98962561	0.2283	22588339
17	2007	0	98962561	0	98962561	0.2075	20534854
18	2008	0	98962561	0	98962561	0.1886	18668049
19	2009	0	98962561	0	98962561	0.1715	16970954
20	2010	0	98962561	0	98962561	0.1559	15428140
21	2011	0	98962561	0	98962561	0.1417	14025582
22	2012	0	98962561	0	98962561	0.1288	12750529
23	2013	0	98962561	0	98962561	0.1171	11591390
24	2014	0	98962561	0	98962561	0.1065	10537627
25	2015	0	98962561	0	98962561	0.0968	9579661
1)TOTALS:		166670000	2055865303	0	2222535303	10.520079	721282010.34

2)Total Project Cost (discounted):-- 721282010
3)Less Terminal Value (discounted):-- 7450142
4)Total Net Project Cost (discounted):-- 713831868
5) Uniform Annual Cost:--- 68562408

Fig. 5c. Wendover, UT Alternative Costs

Project Title: ECTC
Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE
Discount Rate: 0.1
Alternative: PRIMARY STAGING FROM SLC
Economic Life (in years): 25
Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

PROJECT PERIOD	FISCAL YEAR	NON-RECURRING Invstmnt	RECURRING Non-Energy Costs	RECURRING Energy Costs	Total Annual Costs	Disc Factor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6709545	0	12209545	0.8668	10583040
3	1993	8420000	16101637	0	24521637	0.7880	19322697
4	1994	18280000	46762888	0	65042888	0.7164	46593509
5	1995	11400000	55387143	0	66787143	0.6512	43493643
6	1996	31890000	75566575	0	107456575	0.5920	63617006
7	1997	1520000	80091835	0	81611835	0.5382	43923879
8	1998	37240000	92248180	0	129488180	0.4893	63355597
9	1999	0	100203336	0	100203336	0.4448	44570177
10	2000	0	115755766	0	115755766	0.4044	46807142
11	2001	0	115755766	0	115755766	0.3676	42551947
12	2002	0	115755766	0	115755766	0.3342	38683588
13	2003	0	115755766	0	115755766	0.3038	35166899
14	2004	0	115755766	0	115755766	0.2762	31969908
15	2005	0	115755766	0	115755766	0.2511	29063553
16	2006	0	115755766	0	115755766	0.2283	26421411
17	2007	0	115755766	0	115755766	0.2075	24019465
18	2008	0	115755766	0	115755766	0.1886	21835877
19	2009	0	115755766	0	115755766	0.1715	19850797
20	2010	0	115755766	0	115755766	0.1559	18046179
21	2011	0	115755766	0	115755766	0.1417	16405618
22	2012	0	115755766	0	115755766	0.1288	14914198
23	2013	0	115755766	0	115755766	0.1171	13558362
24	2014	0	115755766	0	115755766	0.1065	12325783
25	2015	0	115755766	0	115755766	0.0968	11205258
1)TOTALS:		126750000	2329009119	0	2455759119	10.520079	753870569.91

2)Total Project Cost (discounted):-- 753870570
3)Less Terminal Value (discounted):-- 6079180
4)Total Net Project Cost (discounted):-- 747791390
5) Uniform Annual Cost:--- 71660156

Fig. 5d. Salt Lake IAP, UT Alternative Costs

Project Title: ELECTRONIC COMBAT TEST CAPABILITY
Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE
Discount Rate: 0.1
Alternative: PRIMARY STAGING FROM HAFB
Economic Life (in years): 25
Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

PROJECT PERIOD	FISCAL YEAR	NON-RECURRING Invstmnt	RECURRING Non-Energy Costs	RECURRING Energy Costs	Total Annual Costs	Disc Factor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6630098	0	12130098	0.8668	10514177
3	1993	8420000	16531016	0	24951016	0.7880	19661042
4	1994	23280000	46895973	0	70175973	0.7164	50270597
5	1995	17450000	55343554	0	72793554	0.6512	47405184
6	1996	35700000	76066771	0	111766771	0.5920	66168751
7	1997	6240000	78853756	0	85093756	0.5382	45797866
8	1998	15000000	92429539	0	107429539	0.4893	52562810
9	1999	0	100770220	0	100770220	0.4448	44822325
10	2000	0	115809932	0	115809932	0.4044	46829045
11	2001	0	115809932	0	115809932	0.3676	42571859
12	2002	0	115809932	0	115809932	0.3342	38701690
13	2003	0	115809932	0	115809932	0.3038	35183354
14	2004	0	115809932	0	115809932	0.2762	31984868
15	2005	0	115809932	0	115809932	0.2511	29077152
16	2006	0	115809932	0	115809932	0.2283	26433775
17	2007	0	115809932	0	115809932	0.2075	24030704
18	2008	0	115809932	0	115809932	0.1886	21846095
19	2009	0	115809932	0	115809932	0.1715	19860086
20	2010	0	115809932	0	115809932	0.1559	18054624
21	2011	0	115809932	0	115809932	0.1417	16413294
22	2012	0	115809932	0	115809932	0.1288	14921177
23	2013	0	115809932	0	115809932	0.1171	13564706
24	2014	0	115809932	0	115809932	0.1065	12331551
25	2015	0	115809932	0	115809932	0.0968	11210501
1)TOTALS:		124090000	2330325563	0	2454415563	10.520079	755802269

2)Total Project Cost (discounted):------------------------------------ 755802269
3)Less Terminal Value (discounted):----------------------------------- 5021297
4)Total Net Project Cost (discounted):-------------------------------- 750780972
5) Uniform Annual Cost:-- 71843777

Fig. 5e. Hill AFB, UT Alternative Costs

Project Title: ECTC

Project Objective Description: PROVIDE LOWEST COST AIRCRAFT STAGING BASE

Discount Rate: 0.1

Alternative: PRIMARY STAGING FROM MAAF

Economic Life (in years): 25

Energy In fl. %: 0 PROJECT $: 1990 DOLLARS

PROJECT PERIOD	FISCAL YEAR	NON-RECUR-RING Invstmnt	RECURRING Non-Energy Costs	Energy Costs	Total Annual Costs	Disc Fac-tor	Discounted Annual Costs
0	1990	0	0	0	0	1	0
1	1991	12500000	3845724	0	16345724	0.9535	15585036
2	1992	5500000	6630098	0	12130098	0.8668	10514177
3	1993	8420000	16022190	0	24442190	0.7880	19260094
4	1994	37980000	46498879	0	84478879	0.7164	60516492
5	1995	29070000	54972834	0	84042834	0.6512	54731028
6	1996	38460000	79063278	0	117523278	0.5920	69576748
7	1997	2960000	82112935	0	85072935	0.5382	45786660
8	1998	15100000	92781955	0	107881955	0.4893	52784167
9	1999	0	100093961	0	100093961	0.4448	44521527
10	2000	0	112427351	0	112427351	0.4044	45461260
11	2001	0	112427351	0	112427351	0.3676	41328418
12	2002	0	112427351	0	112427351	0.3342	37571289
13	2003	0	112427351	0	112427351	0.3038	34155718
14	2004	0	112427351	0	112427351	0.2762	31050652
15	2005	0	112427351	0	112427351	0.2511	28227866
16	2006	0	112427351	0	112427351	0.2283	25661696
17	2007	0	112427351	0	112427351	0.2075	23328815
18	2008	0	112427351	0	112427351	0.1886	21208013
19	2009	0	112427351	0	112427351	0.1715	19280012
20	2010	0	112427351	0	112427351	0.1559	17527284
21	2011	0	112427351	0	112427351	0.1417	15933894
22	2012	0	112427351	0	112427351	0.1288	14485358
23	2013	0	112427351	0	112427351	0.1171	13168508
24	2014	0	112427351	0	112427351	0.1065	11971371
25	2015	0	112427351	0	112427351	0.0968	10883064
1)TOTALS:		149990000	2280859470	0	2430849470	10.520079	764519147.59

2)Total Project Cost (discounted):-- 764519148

3)Less Terminal Value (discounted):-- 6274912

4)Total Net Project Cost (discounted):-------------------------------------- 758244236

5) Uniform Annual Cost:-- 72672371

Fig. 5f. Michael AAF, UT Alternative Costs

Rank	Staging Alternative	Total Constant Dollar Cost (1990 $)	Figure Number
1	Delta	$ 2,176,391,480	5.b
2	Wendover	2,222,535,303	5.c
3	Remote	2,284,859,922	5.a
4	Michael AAF	2,430,849,470	5.f
5	Hill AFB	2,454,415,563	5.e
6	Salt Lake IAP	2,455,759,119	5.d

The total constant dollar cost can be found in row number 1 (Totals), in the sixth column of the referenced figure. Recall that constant dollar costs are not discounted. In constant 1990 dollar terms, the Delta, Utah alternative was the lowest cost staging alternative followed by the Wendover, Utah alternative. The Remote alternative was the third lowest cost alternative. From these results, one can see that there was a change in the rank of the alternatives compared to the present value results. This signifies that there is a point of indifference somewhere in the life cycle of the CA. The point of indifference is when the alternatives referred to are equal in cost at some point in that year.

The point of indifference between the Delta, Utah and the Remote alternatives is in the 17th year of the analysis (FY 2007). Up to the 17th year, the Remote alternative is the lowest cost alternative. The point of indifference

between the Wendover, Utah and the Remote alternative is in the 19th year of the analysis (FY 2009).

The two methods (present value versus constant dollars) result in different rankings. This is because the Remote alternative's higher outyear costs are discounted heavily (multiplied by increasingly smaller fractional numbers in the outyears) in the present value method reflecting the time value of money. In constant dollar terms, the higher outyear costs are not discounted. Therefore, this causes the shift in the ranking of the alternatives.

Sensitivity Analyses

As discussed previously, the ECTC mission workload (the number of missions for each ECTC use category) is the major cost driver in this CA. Because of this, a sensitivity analysis was done which focused on the mission workload. Also, there is much debate in financial circles concerning the discount rate that is used when capital projects are evaluated. The Air Force recommends that the discount rate be lowered to 5% for sensitivity analysis purposes (5:9) to reflect a lower opportunity cost of "diverting . . . capital (investment funds) from the private sector into the public sector" (5:9). Because of this, a sensitivity analysis was done on the discount rate.

The first of the two sensitivity analyses addressed the mission workload assumptions. ECTC mission levels were

increased and decreased by 10% for each ECTC use category. The results of this sensitivity analysis are presented below.

Results of Mission Workload Sensitivity Analysis

Rank	Staging Alternative	10% Reduction Total Net PV Project Cost	10% Increase Total Net PV Project Cost
1	Remote	$ 628,078,408	$ 753,774,545
2	Delta	646,139,904	757,011,392
3	Wendover	655,653,296	772,037,330
4	Salt Lake IAP	688,904,696	798,529,444
5	Hill AFB	689,883,048	813,421,771
6	Michael AAF	700,942,886	815,459,977

When the ECTC mission workload was varied plus/minus 10%, the ranking of the alternatives did not change. This can be interpreted as an estimating confidence interval: If the ECTC mission workload was under- or overestimated by 10% or less, the analysis still points toward the Remote alternative as the lowest cost staging option under the present value method.

The second sensitivity analysis runs each alternative at discount rates of 1% thru 9%. These results are presented here by alternative. Dollars are in billions and the alternatives are in the same ascending order as they were

when they were calculated at a 10% discount rate. The cost of the lowest cost alternative under each discount rate is in bold.

Results of Discount Rate Sensitivity Analysis

($ in billions)
Discount Rates

Altern.	9	8	7	6	5	4	3	2	1
Remote	**.763**	**.847**	.943	1.055	1.185	1.337	1.517	1.729	1.980
Delta	.772	.850	**.940**	**1.044**	**1.165**	**1.306**	**1.471**	**1.665**	**1.895**
Wndvr	.784	.864	.956	1.063	1.186	1.331	1.500	1.700	1.935
Slt Lk IAP	.826	.915	1.018	1.138	1.278	1.441	1.633	1.860	2.123
Hill AFB	.828	.918	1.021	1.140	1.281	1.441	1.634	1.860	2.130
Michael AAF	.835	.923	1.024	1.142	1.280	1.439	1.627	1.848	2.111

As can be seen from viewing the above results, when the discount rate was lowered from 8% to 7%, the Delta, Utah alternative replaced the Remote alternative as the lowest cost alternative. In other words, at a discount rate between 7% and 8%, the Delta, Utah and Remote alternatives are equivalent in cost.

When the discount rate was lowered from 5% to 4%, the Wendover, Utah alternative also became cheaper than the Remote alternative. In other words, at a discount rate between 4% and 5%, the Wendover, Utah and Remote

alternatives are equivalent. It is interesting to note that at 4%, the Delta, Utah alternative remained the lowest cost alternative followed by the Wendover, Utah alternative.

To sum up, at a discount rate above 8%, the Remote alternative is the lowest cost alternative. At a discount rate of 7% to 5%, the Delta, Utah alternative is the lowest cost alternative followed by the Remote alternative. At a discount rate of 4% and under, the Delta, Utah alternative remains the lowest cost alternative, the Wendover, Utah alternative is the second lowest cost alternative, and the Remote alternative is the third lowest cost alternative.

Recall that the preferred method of evaluating capital projects is the net present value method. In terms of present value, the results indicate that the Remote alternative is the lowest cost solution. This solution is robust with regard to a plus/minus 10% change in the mission workload assumptions. However, this solution is not robust when the discount rate is lowered to 7%.

VI. Conclusions and Recommendations for Further Research and Study

The focus of this research was to find the lowest cost aircraft staging base(s) for the test and support aircraft that will fly over the ECTC. Specifically, the objective of this study was to determine the lowest cost staging base option that would reduce the life cycle cost of the ECTC. To accomplish that objective, a CA was performed. This CA examined six alternative staging options. A series of research questions were addressed as part of the CA. Each of the research questions are answered below. Following that, some implications for management are presented. The chapter concludes with some recommendations for further research and study.

Responses to Research Questions

1. What is the total mission time for each ECTC staging location?

The following are the total mission times used for each alternative staging location for tactical and strategic aircraft. The flying times were calculated as described in Chapter IV.

For Hill AFB, the tactical flying time is 1.99 hours and the strategic flying time is 4.14 hours.

For Michael AAF, the tactical flying time is 1.58 hours and the strategic flying time is 3.65 hours.

For Salt Lake City IAP, the tactical flying time is 1.88 hours and the strategic flying time 4.02 hours.

For Wendover, Utah, the tactical flying time is 1.83 hours and the strategic flying time is 3.95 hours.

For Delta, Utah, the tactical flying time is 1.49 hours and the strategic flying time is 3.43 hours.

For the Remote basing alternative, Nellis AFB was used for tactical missions and the flying time is 2.01 hours. For the strategic missions, a combination of Ellsworth/Dyess/McChord AFBs was used. For Ellsworth AFB, the flying time is 6.69 hours. For Dyess AFB, 7.92 hours is used. For McChord AFB, 7.18 hours is used.

2. What are the operating and maintenance costs for this project (exclusive of operating the ECTC electronic simulation equipment).

The 6545 Test Group, who manages the Utah Test and Training Range, provided factors to cost operations and maintenance for facilities and nonfacilities. For facilities, an annual cost of $7.62 per square foot was used. For nonfacilities, such as runways and taxiways, an annual cost of $1.36 per square foot was used.

3. How many missions and aircraft are projected to use the ECTC?

Figure 4a-4d displays the number of missions, aircraft categories, and the number of participants within each aircraft category that will use the ECTC. Figure 4a-4d is discussed in Chapter IV.

4. What is an acceptable, existing capital investment model to evaluate the alternative staging locations?

The aspects of an acceptable model to evaluate alternative staging locations are presented in Chapter II under "Capital Investment Evaluation Methods." The net present value model incorporating terminal value calculations was used in this CA.

5. Based on the above inputs, what is the lowest cost aircraft staging location?

As discussed in Chapter V, the lowest cost staging alternative is the Remote staging alternative.

6) Is the lowest cost staging option sensitive to changes in the following CA inputs:

a) The mission workload.

b) The discount rate.

As discussed in Chapter V, this solution is robust with regard to a plus/minus 10% change in the mission workload assumptions. However, this solution is not robust when the discount rate is lowered to 7%.

Implications for Management

This CA firmly points to using existing, remote bases for aircraft staging for the ECTC instead of constructing new bases or modifying existing bases. There are three reasons for this.

1) The net present value results in which the Remote alternative was the lowest cost alternative.

2) The results of the mission workload sensitivity analysis which upheld the Remote alternative as the lowest cost alternative.

3) The results of the discount rate sensitivity analysis also upheld the Remote alternative as the lowest cost alternative when a discount rate of 8% or greater is assumed. Recall that at a discount rate of 7%, the Delta, UT alternative replaced the Remote alternative as the lowest cost alternative. Traditionally, much of the argument concerning discount rates for government projects is centered around what the real opportunity cost is for money that is diverted from the private sector into government investments. The Treasury rate is usually cited as an alternative measure of this opportunity cost (5:14). If the Treasury rate is used, the Air Force recommends the use of "the current interest rate on Treasury securities whose maturity most closely corresponds to the period of the analysis (5:14).

The life cycle of the CA is 25 years. Currently, the interest rate on Treasury securities maturing in 2015 (which is the last year of the CA) is 10.63% (21:B-6). This interest rate, which would be used as a discount rate in this case, is well above the 7% discount rate that changed the ranking of the alternatives. The point here is that it is unlikely that a discount rate of 7% can be seriously considered as a true opportunity cost of capital for this CA.

In summary, the Remote alternative is a robust solution as the lowest cost alternative.

Recommendations for Further Research and Study

There are two avenues that should be pursued further relating to this CA. The first concerns the ECTC and the second concerns capital investment evaluation. Both of these avenues are discussed below.

Further ECTC Research

As described in Chapter V, the CA for the ECTC is developed based on a large amount of workload and mission participant estimation. The workload and mission participant estimation is developed from assumptions. These assumptions are based on expert opinion using the Roundtable method of estimation. The ECTC planning board served as the experts for this estimation.

The workload and mission participant estimations represent the largest cost driver in the CA. From an analytical standpoint, it would be fruitful to look at other techniques for estimating the ECTC workload as a way of validating the estimations derived from the ECTC planning board. From a broader perspective, range workload estimation could be looked at beyond just the ECTC. This would be of value since test ranges have lived with workload estimation problems for years.

The sensitivity analysis (described in Chapter V) was performed because of the importance the ECTC workload as a cost driver. It lends confidence that the choice of the Remote staging alternative as the lowest cost option is valid even if some error was made estimating ECTC workload.

Further Capital Investment Evaluation Study

Capital investment evaluation is essential when resources are scarce. The Department of Defense presides over a resource base which is scarce. Proposed capital projects must be evaluated so that the alternative chosen is the most cost effective (in the case of an economic analysis (EA)) alternative, or the lowest cost alternative (as is the case for a cost analysis). The principles for conducting an EA or CA are identical, except that an EA also weighs the nondollar benefits of each alternative when making the investment decision. As shown in the ECTC CA, the CA

chooses the lowest cost alternative without taking nondollar benefits into account.

To help study capital investment evaluation, the Appendix contains a capital investment evaluation case study. The case study contains a similar, less complicated capital investment evaluation scenario. The case study contains data so that it may be used to perform an EA or CA depending on the objective. The case study's level of sophistication merits that the student should have a basic background in cost accounting subjects such as cost definition, present value, life cycle cost analysis, and depreciation.

CA Summary

This CA shows that the Remote alternative is the lowest cost staging alternative under the present value method, and that this solution is robust under sensitivity analyses concerning the mission workload assumptions and the discount rate used. In constant dollar terms, the Delta, Utah alternative is the lowest cost alternative.

Appendix: Capital Investment Evaluation Case Study

General Issue

In the past several years, there has been a considerable amount of criticism from Congress and many other sources concerning the lack of operational testing of the Air Force's new and modified weapons systems. The problems experienced with the B-1B bomber and the Advanced Medium Range Air-to-Air missile (AMRAAM) have served to highlight this problem and galvanize the criticism. Many of the critics contend that the Air Force needs a test range that could be used for operational testing.

In response to the above, the Air Force is in the process of programming for an operational test range.

Specific Situation

There are four alternative aircraft staging bases under consideration. The staging base that is chosen will be used by the test and support aircraft that will use the operational test range. Many of the aircraft that will use the new test range will be highly classified test aircraft with visual sight restrictions. The operational testing capability will be installed on an existing Air Force range.

Staging Base Alternatives

The following gives a brief description of each staging base alternative.

Base A: Is an existing air base that hosts an active duty and a reserve F-16 fighter wing. Base officials have had problems with local community objections to large amounts of nighttime flying from the F-16 operations. Base A experiences approximately 60 days a year (during the winter) when flying operations are discontinued because of weather. Base A currently manages the range that will be used for the operational testing.

Base B: Is a former auxiliary airfield with several existing dilapidated World War II (WW II) vintage facilities. The runway needs extensive repairs to handle heavy fighter aircraft and transports. There is a small local town adjacent to the airfield and a major interstate

is only one mile away.

Base C: Is an existing army airfield located in a remote, rural area. The base has a highly classified army mission that it has hosted since WW II. It has several facilities that can be used for the test range aircraft, but the airfield will need extensive repairs.

Base D: Is a small, little used Bureau of Land Management (BLM) airfield. It has very little ongoing activity. The closest town is 30 miles away. It would need extensive investment to host the staging mission. BLM has agreed to let DoD annex the land where the airfield is located but wants to maintain rights to land aircraft there.

Below is a table that lists the round trip flying times for each of the above bases.

Base Round Trip Flying Times

Base	Flying Times(hrs)
A	2.3
B	1.7
C	2.0
D	1.4

Investment Costs

All the alternative staging bases need differing amounts of military construction and other investment so that they can function as an aircraft staging base. The following is an itemized list of the investment needed for each base. The first list itemizes the common investment for all alternatives. These facilities and other investments will be constructed at Base A no matter which alternative is chosen. The four investment lists that follow are alternative specific.

Common Investments

Item	Year of Construction	AF Need Date	Cost ($M)	Sq Ft
Mission Control Center	91	93	10.0	53500
Combined Test Force Facility	95	96	6.0	67000
Radar Site	92	93	1.5	
Range Maintenance Facility (S)	93	94	4.0	34800
Hlcptr Hngr(S)	93	94	1.0	12060
Apron (S)	93	94	.21	76120
Range Maintenance Facility (N)	94	95	3.0	26100
POV Parking	94	95	.03	12600
Hlcptr Hngr(N)	93	94	1.0	12060
Apron (N)	93	94	.21	76120
Access Roads	94	95	1.25	158400

(S) - South Part of Range (N) - North Part of Range

Base A

Item	Year of Construction	AF Need Date	Cost ($M)	Sq Ft
Test A/C Hngr	94	96	16.0	104300
Threat A/C Hngr	96	98	11.0	66800
Hlcptr Hngr	96	97	3.0	24000
Electromagnetic Chamber	96	97	15.0	30000
Aprons	95	96	3.36	1200000

Taxiway	95	96	.75	225000
Fueling Area	94	95	1.0	40000
AGE Area	96	97	.1	3750

Base B

Item	Year of Construction	AF Need Date	Cost ($M)	Sq Ft
Test A/C Hngr	94	96	16.0	104300
Threat A/C Hngr	96	98	11.0	66800
Hlcptr Hngr	96	97	3.0	24000
Electromagnetic Chamber	96	97	15.0	30000
Aprons	95	96	3.36	1200000
Taxiway	95	96	.75	225000
Runway	95	96	12.0	1000000
Fueling Area	94	95	1.0	40000
AGE Area	96	97	.1	3750
POV Parking	96	97	.04	15750
Support Vehicle Parking	96	97	.06	25000
Billeting/Dining Hall	95	96	2.0	52400
Maintenance & Scrty Lghtng	95	96	.9	
Fence	95	96	.1	
Access Roads	95	96	.24	31680
Entry Cntrl Gt	95	96	.1	50
Nvgtnl Aids	97	98	3.0	

Mntns Storage	97	98	.1	1600
Mntns Ldng Area	97	98	.1	4000
Jet Fuel Tnks	94	96	1.2	

Base C

Item	Year of Construction	AF Need Date	Cost ($M)	Sq Ft
Test A/C Hngr	94	96	16.0	104300
Threat A/C Hngr	96	98	11.0	66800
Hlcptr Hngr	96	97	3.0	24000
Electromagnetic Chamber	96	97	15.0	30000
Aprons	95	96	3.36	1200000
Taxiway	95	96	.75	225000
Runway	95	96	12.0	1000000
Fueling Area	94	95	1.0	40000
Jet Fuel Tnks	94	96	1.2	
AGE Area	96	97	.1	3750

Base D

Item	Year of Construction	AF Need Date	Cost ($M)	Sq Ft
Test A/C Hngr	94	96	16.0	104300
Thrt A/C Hngr	96	98	11.0	66800
Hlcptr Hngr	96	97	3.0	24000
Electromagnetic Chamber	96	97	15.0	30000
Aprns	95	96	3.36	1200000

Taxiway	95	96	.75	225000
Runway	95	96	12.0	1000000
Fueling Area	94	95	1.0	40000
AGE Area	96	97	.1	3750
POV Parking	96	97	.04	15750
Support Vehicle Parking	96	97	.06	25000
Billeting/Dining Hall	95	96	2.0	52400
Maintenance & Scrty Lghtng	95	96	.9	
Fence	95	96	.1	
Access Roads	95	96	4.0	1013760
Refueling Truck Parking	96	97	.05	20000
Runway Lghtng	95	96	1.0	
Taxiway Lghtng	95	96	.6	
Approach Lghtng	95	96	.9	
Apron Lghtng	95	96	.4	
Arrstng Barrier	94	96	.5	
Cntrl Twr/Fire Sttn/Med Clnc	95	96	1.3	9075
Petro Ops/Vehicle Mntnnc Fclty	95	96	.25	5450
Gas Station	95	96	.3	5000
Scrty Systms	95	96	.2	
Runway Visual Range Unit	95	96	.1	180
Ceilingometer	96	97	.1	

Smll Arms Strg	96	97	.05	144
Entry Cntrl Gt	95	96	.1	50
Nvgtnl Aids	97	98	3.0	
Mntns Storage	97	98	.1	1600
Munitions Loading Area	97	98	.1	4000

Aircraft Flying Hour Data

The following is the flying activity, by fiscal year, that is associated with the operational test range.

Analysis Year	Fiscal Year	Tactical Sorties	Strategic Sorties
6	96	200	100
7	97	210	100
8	98	250	120
9	99	250	130
10	2000	300	150

After FY 2000, the flying activity will be constant at the FY 2000 level. For Alternative A, 30% of the tactical missions require refueling. For Alternative C, 20% of the tactical missions require refueling. To account for this, .3 hrs should be added to the flying time of the appropriate percentage of tactical sorties requiring refueling for the Alternative A or C. A refueling sortie should be added to each tactical sortie that is refueled. Refueling sorties ar 4 hrs in length.

The following are the flying hour cost for tactical, strategic, and refueling aircraft.

Tactical	Strategic	Refueling
$2500	$5200	$4200

Other Data

Utility and maintenance costs are allocated at $7.62 per square foot for facilities. All nonfacility maintenance costs and road maintenance costs are accounted for at $1.36 per square foot.

Facilities should be depreciated at 1.7% per year.

For the purposes of this analysis, the costs for personnel are considered equal and therefore not tabulated.

All costs are in constant 1991 dollars. No escalation is required.

The costs of the equipment to be installed on the range itself are common costs and do not need to be tabulated.

Required

Perform an economic analysis, in 1991 constant dollars, based on the following:

1) 25 year economic life cycle.

2) Value of depreciated facilities added in at the end of the analysis.

3) 10% mid-year discount factors.

Additionally, compute the uniform annual cost and rank the benefits of each alternative.

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Vita

Captain Joseph J. Landino, Jr. [redacted] graduated from Branford High School in Branford, Connecticut in 1976 and attended Franklin Pierce College, graduating cum laude with a Bachelor of Science in Economics in May 1980. He then attended the University of Denver and graduated with a Masters in Public Administration in September 1981. In May 1985, he was commissioned through Officer Training School and served his first tour of duty as a Cost Analysis Officer for the 1606 Air Base Wing at Kirtland AFB, New Mexico until October 1986. He was then chosen to serve as Chief, Cost Analysis for the Air Force Operational Test and Evaluation Center at Kirtland. There he was responsible for directing all cost analysis activities including audit, budget analysis, and program evaluation until entering the School of Systems and Logistics, Air Force Institute of Technology (AFIT), in May 1989. While attending AFIT, he was certified by the Institute of Cost Analysis as a Certified Cost Analyst, and was invited into the AFIT Chapter of the Sigma Iota Epsilon Honorary Management Fraternity.

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13. ABSTRACT *(Maximum 200 words)*
This study's purpose was to identify the lowest cost aircraft staging base(s) for the Air Force's proposed Electronic Combat Test Capability (ECTC). The ECTC will be an electronic simulation of a Soviet integrated air defense sector. If constructed, the ECTC would be located at the Utah Test and Training Range. A literature review revealed that there has been a need for a test capability like the ECTC since the Vietnam War era. To find the lowest cost aircraft staging base(s), a 25 year life cycle cost analysis (CA) was performed for the sponsoring agency, the Air Force Operational Test and Evaluation Center (AFOTEC). The CA evaluated six staging alternatives that were identified by AFOTEC. Two significant portions of the CA were to estimate the investment costs for each alternative, and to cost the aircraft mission workload projected for the 25 year life cycle. The CA revealed that the lowest cost staging option was to stage aircraft operations from their home bases instead of constructing a new or modifying an existing base.

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